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Simulation of Urban Gas Leakage Based on Google Earth

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Abstract

A 3D computational model predicting extent of gas leakage has been built up based on the building location from Google Earth. On the basis of computational results, the rules of the concentration field, the concentration differences at the near wall and far wall, and the velocity field change with the leakage time, has been analyzed, respectively. It provided reliable data for the city gas safe operation and emergency management.

Keywords: Google Earth; city gas leakage; numerical simulation

Nomenclature

K Turbulence energy (J)
G_b a buoyancy production term
Y_M Impact of compressible turbulence pulsation expansion to the total dissipation rate
σ_k TKE Prandtl Number
X, Y Cartesian coordinate values of architectural feature point relative to the datum point
E, N Latitude and longitude of the architectural feature point
a, b Conversion parameter in Guangzhou area
Greek symbols
ε Dissipation rate
μ Viscosity coefficient of laminar (pa • s)
μt Viscosity coefficient of turbulence (pa • s)

1. Introduction

With the development of China's civilian gas industry, cities with urban gas pipeline have risen rapidly. Therefore, the issues of city gas security are becoming more important. The urban gas's characteristics (inflammable and explosive) make the city gas projects onerous and complicated [1]. Mismanagement or improper use may lead to more frequent failures, causes casualties and property losses.

On the aspect of Gas diffusion mechanism and transport control, a lot of research and computational models have been carried out. For example, DEGADIS model predicts the distance of gas diffusion in an overflow accident; FEM3A model simulates the range of vapor diffusion with considering the impact of terrain and obstacles; Gaussian model is suitable for the continuous dot diffusion of neutral gas. As the diffusion of pipeline gas affected by weather condition, emission sources,

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the complexity of the underlying surface, the process of Physical, Chemical and Biological coupling and etc, it can't be predict properly by the above models [2]. Therefore, it is important to study rules of urban gas leakage diffusion combined with meteorological fields and terrain [3].

In recent years, through Google Earth, which is a map software produced by Google, to get the high-resolution satellite images and physiognomy around the world is available.

This paper analyzed the terrain images around the urban leakage source supplied by Google earth, established CFD 3D model, and made a research of gas diffusion combined with physiognomy, obstructions distribution, meteorological conditions, leak position and other factors.

2. Diffusion of urban gas leakage

The east campus of Sun Yat-sen University covers an area of 1,131,700 square meters, including teaching area of 875,300 square meters, 256,400 square meters of living area, a total of 34 buildings including Mingde Park, Gezhi Park, canteens and etc, as shown in Fig 1.

Fig.1. Schematic diagram of Sun Yat-sen University East Campus

3. Mathematical model of gas diffusion

The CH4 diffusion caused by urban gas pipeline leakage is a typical phenomenon of convection mass transfer in open area. In strict truth, it is a kind of transfer or transport of CH4 rather than a kind of diffusion. Because in the process of convective mass transfer, it included not only the fick diffusion due to the molecular microscopic thermal motion, but also the mass advection caused by macroscopic relative motion of the fluid [4]. It belongs to the low Mach number flow because the speed of gas diffusion buoyancy flow is far less than the speed of sound [5]. This paper used FLUENT to carry out numerical simulation, selected the standard k - ε model as a turbulence model. The basic control equation of gas diffusion and convective mass transfer is as follow:

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_j}(\rho \overline{u}_i)=0 \tag{1}$$

$$\frac{\partial}{\partial t}(\rho \overline{u}_i)+\frac{\partial}{\partial x_j}(\rho \overline{u}_i \overline{u}_j)=\rho f_i-\frac{\partial \overline{p}}{\partial x_j}+S_u \tag{2}$$

$$\frac{\partial(\overline{\rho Y_l})}{\partial t}+\frac{\partial(\overline{\rho Y_l u})}{\partial x}+\frac{\partial(\overline{\rho Y_l v})}{\partial y}=div(\rho D grad(\overline{Y_l}))+S_Y \tag{3}$$

$$\frac{\partial(\overline{\rho T})}{\partial t}+\frac{\partial(\overline{\rho T u})}{\partial x}+\frac{\partial(\overline{\rho T v})}{\partial y}=div(\rho C_p grad(\overline{T}))-\frac{\partial q_j}{\partial x_j}+S_q \tag{4}$$

$$\frac{\partial(\overline{\rho S})}{\partial t}+\frac{\partial(\overline{\rho S u})}{\partial x}+\frac{\partial(\overline{\rho S v})}{\partial y}=div(\rho C_p grad(\overline{S}))-\frac{\partial q_j}{\partial x_j}+S_q \tag{5}$$

$$\rho\frac{\mathrm{d}k}{\mathrm{d}t}=\frac{\partial}{\partial x_i}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right]+G_k+G_b-\rho\varepsilon-Y_M \tag{6}$$

$$\rho\frac{\mathrm{d}\varepsilon}{\mathrm{d}t}=\frac{\partial}{\partial x_i}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{7}$$

Where:

C_1 = empirical constant with values of 1.44

C_2 = empirical constant with values of 1.92

C_3 = empirical constant with values of 0.09

σ_k = TKE Prandtl Number with values of 1.0

4. Modeling basis on Google Earth

Make secondary development on Google Earth can get the local geography. After related data conversion, a 3d model can be set up. As shown in Fig.2. Modeling procedure is as follows:

(1) Extract the buildings' Latitude and longitude from Google Earth;

(2) Select datum point, O(E113.37893，N23.05766), and translate to Cartesian coordinate data by using Equation (8) and (9) as follows [6]:

$$X=(E-113.37893)*a \tag{8}$$

$$Y=(N-23.05766)*b \tag{9}$$

(3) Get the above data into AutoCAD; make a plan of Sun Yat-sen University East Campus, as shown in Fig.2.

(4) Get the data from step 3 into Gambit, and create a 3D model through face extrude.

(5) Defined the area of calculation, as shown in Fig.3.

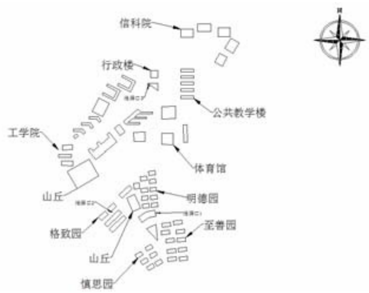

Fig.2. The plan of Sun Yat-sen University East Campus

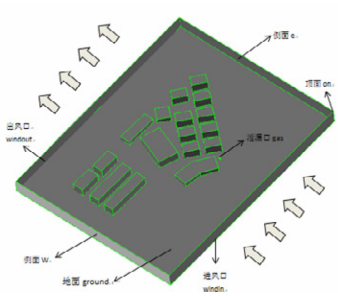

Fig.3. The area of calculation

5. Results and analysis

By setting the ambient wind speed, the leak rate as well as the location of the leaking hole, the flow field of gas diffusion, the Methane concentration changes over time, and the flow around a building impact on the flow and mass transfer process can be simulated by FLUENT, shown as Fig.4 to Fig 6.

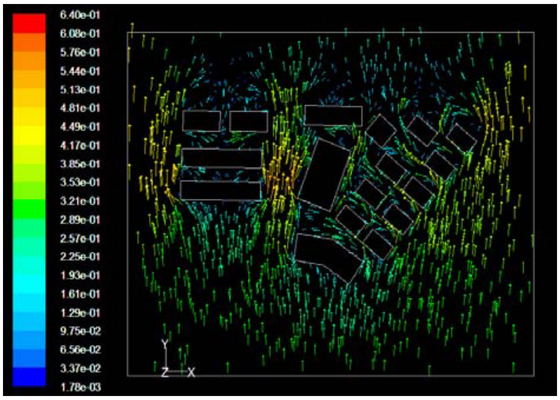

Fig. 4. The vector field of gas leakage diffusion

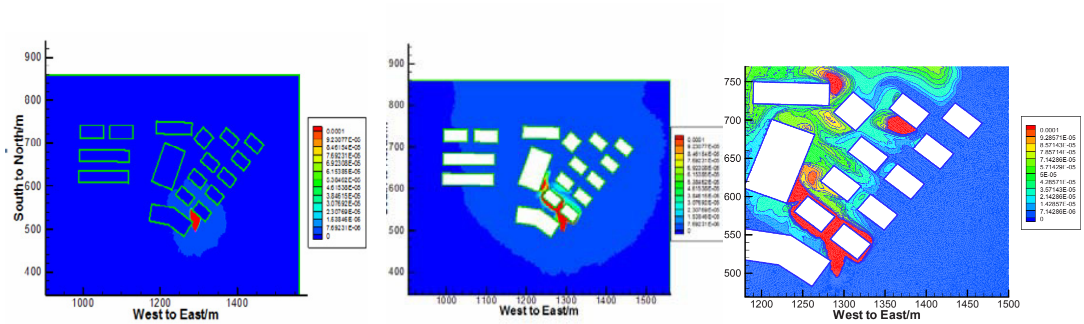

Fig.5. The distribution of Methane concentration (Volume fraction) at 10s, 5mins and 20mins, respectively.

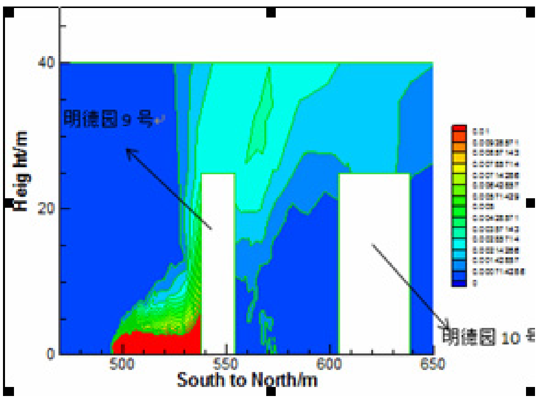

Fig.6. The distribution in the height direction of Methane concentration at 20mins.

In the non-restricted space, the risked areas of Gas concentration are mainly concentrated in the downwind direction of the leaking hole. In the meanwhile, the gas will accumulate behind the buildings cause by the effect of the flow around a building.

6. Conclusion

This paper took the east campus of Sun Yat-sen University as a model with the aid of Google Earth, and utilized FLUENT to make a simulation. These simulations showed the following:
(1) Contrast with the simulation of Gaussian plume model, it is found that the gas concentration near the leaking hole decline faster at the beginning, but slower soon afterwards.
(2) Diffusion region is related with the direction of leakage. High concentration of gas emerged a narrow elliptical area below the leaking hold.
(3) The distribution area of methane grows over time, but the risked area mainly concentrated near the leaking hole. The concentration of peripheral methane is so low that it can't pose a risk for humans.
(4) Methane tends to concentrated in the area between the buildings. To avoid false positive, the monitoring points should not be placed on these position.

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